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RESEARCH PAPER

Storage performance of forced ventilated, natural ventilated, and traditional methods on the quality of onion bulbs

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Key Message: The study aimed to assess the effect of storage methods on the quality of onion bulbs. It concludes that forced ventilated wooden structure with simple modification can improve the quality of onion bulbs and maximize their storage period.

Abstract: An experiment investigating the losses of onion bulbs occurring during the storage in different storage structures was conducted at the Department of Farm Structures, Sindh Agriculture University, Tandojam. Freshly harvested onion bulbs free from defects were collected from the local market of Nasarpur and were then placed in different storage structures (forced ventilated wooden structure, naturally ventilated wooden structure, and traditional method) for 60 days. The quality in terms of different parameters that is physiological loss in weight, rotting, sprouting and firmness were carried out at an interval of 10 days. The results showed that the storage time and storage method had a significant effect on the quality of onion bulbs. Weight loss (0-23.5%), rotting (0-26.8%) and sprouting (0-15.2%) of onion bulbs showed an increasing trend throughout the storage period (60 days). However, firmness of the onion bulb decreased with increasing storage period (8.3 to 3.2 lbs). Forced ventilated wooden structure maintained lowest weight loss (14.8%), rotting (7.4%) and sprouting (7.8%) with highest firmness (5.6 lbs), followed by naturally ventilated wooden structure and traditional method respectively. Ambient temperature and relative humidity were lower in forced ventilated wooden structure followed by natural ventilated wooden structure and traditional method respectively. The present study concludes that forced ventilated wooden structure resulted to be better in maintaining the quality parameters of onion bulbs, the adoption of this method is strongly suggested to reduce the storage losses at farm level.

Keywords: Humidity, Onion, Quality, Storage method, Temperature,

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Introduction

Onion (*Allium cepae* L.) is a plant of economic importance and is being widely cultivated throughout the world (Awuah et al., 2009). Onion is used as a condiment either as green leaves or mature bulb in salad and preparation of other dishes (Khan et al., 2005). The onion is a rich source of phosphorous, calcium, sodium and fiber, it is dependent upon several factors (Khokhar, 2019) and is also considered to be an important component of folk medicine (Nayerabi & Ahmed, 2001; Marwat et al., 2011; Tedesco et al., 2015). The Global production of onion is about 64 million tons, where Pakistan contributes about 2.015 million tons making it the 8th largest producing country (Nabi et al., 2010).

Onion is a seasonal crop therefore bulbs are usually to be stored till next harvest or for a longer period due to seasonal glut in the market (Wright et al., 2001). Onion being produced in Pakistan are in excess generally, whereas the growers temporarily store their produce in the field, under shelters and/or rooms under ambient conditions for 5 - 6 months (Ahmad et al., 2005). Onion is a low perishable crop, where improper storage occurs deterioration due to rotting, sprouting, and physiological weight loss (Biswas et al., 2010; Wang et al., 2019). The long-term storage of onion to catch high off-season prices will result in more benefit (Jahanzab et al., 2007). Owing to its an unpleasant pungency property and tearing effects while cutting, ready-to-use diced onions are very convenient for end-use consumers and food service companies, where preserving the freshness and functional consistency of diced onions remains still a concern in the food industry (Fonseca et al., 2018). Rate of respiration in onions increases with rotting and re-growth; whereas heat generation consequently enhances moisture loss, reducing its shelf life during storage (Trevisan et al., 1999; Kaka et al., 2019; Selivanova et al., 2019). The fungus causing black mold is the main member of *Aspergillus*, and is predominantly a plant pathogen responsible for post-harvest deterioration of stored onion bulbs (Sibi et al., 2012; Chattha et al., 2017). It has been documented that, with Fusarium spp. losses due to disease can exceed 90 percent of total production, this reflects up to 30 per cent of the losses (Rasiukeviciute et al., 2016). Post-harvest operations and storage conditions such as temperature, relative humidity and air composition are crucial factors in managing and reducing the water losses (Yoo et al., 2012; Ali et al., 2018).

The rationale behind such post-harvest losses occurring is the unavailability of proper storage facilities during post-harvest storage phase (Ahmad et al., 2005). Improper handling of onion bulbs during or after harvesting can significantly be affected by mechanical means, that will affect their quality, storage life and surface or internal bruising, contributing to both water losses and storage diseases (Maude, 1983). During off-season the efficient storage facility for onion plays an important role for the consumers as well as for the producers which ultimately prevents serious losses due to rotting and sprouting (Anbukkarasi et al., 2013). A study was carried out by Imoukhuede & Ale (2015) about constructing storage structures with different roofs. They reported that the basket kept at room temperature proved to be the best for storing onion than those of asbestos, thatched and iron roof. The onions stored in conventional storage structures have no aeration at bottom, which results in bruising and decaying of onions (Soomro et al., 2016). However, onions stored in full ventilated conditions at bottom and sides with raised structure above ground reduced the storage losses from 70.0 to 99.2% during five months of storage (Ranpise et al., 2001). Sun et al. (2020) detected rotting in onions, particularly small and localized rots by transmittance system. Adamicki (2005) stated that storage conditions are critical for regulating the rate of sprouting, rooting and transpiration and thereby extending the shelf life of onion bulbs, while post-harvest handling including storage temperature and relative humidity are important to maintain the quality of onion bulbs (Brewster, 2008; Zudairea et al., 2019). Onion cold storage is uncommon, and the growers usually store onions using conventional techniques (Tariq et al., 2005), in comparison storing onion bulbs at high temperature (18-21 ºC) leads to increasing losses (Krawiec, 2002).

Onion storage facilities being used by the majority of farmers in Sindh province are unable to protect the onion from deterioration and are inadequate to meet the requirements of food in terms of quality and quantity. Therefore, it is necessary to know the ways and to develop the structures in which onion bulbs could be stored for a longer time duration without deteriorating at farm level. The current study was therefore designed to investigate the effects of different storage methods on the quality of onion bulbs.

Materials and Methods

Experimental site

The present study was carried out to investigate the losses of onion bulbs occurring in different storage structures. The experiment was carried out at the Department of Farm Structures, Faculty of Agricultural Engineering, Sindh Agriculture University Tandojam, Pakistan. The experimental area is located at Latitude of 25.42 ºN and Longitude of 68.53 ºE at an elevation of about 12 m above sea level.

Onion bulbs

Freshly harvested onion bulbs of Nasarpur variety free from defects were collected from the local market of Nasarpur and were placed in different storage structures that is forced ventilated wooden structure, naturally ventilated wooden structure, and traditional storage method for 60 days (Fig. 1). Onion bulbs weighing fifteen kilograms were kept in each storage method.

Forced ventilated wooden structure

Forced ventilated structure having a capacity of 15 kg was constructed from wooden frame. The air was fed by the fan fixed in the duct provided at the bottom of the structure twelve hours per day. The sides of the structure were covered with thin plywood sheets, where the wooden strips were placed at a distance of one inch (Fig. 1a).

Naturally ventilated wooden structure

Natural ventilated structure was made from wooden strips keeping all sides, top and bottom fully ventilated naturally. The wooden strips were placed at a distance of one inch, where for bottom side ventilation the structure was raised four inches from the ground (Fig. 1b).

Traditional Storage

The onion bulbs in this method were kept on a concrete floor under shade. The sides were then blocked by bricks to avoid spreading of onions. This is the most common method being used to store onion bulbs (Fig. 1c).

Samples collection and analysis

The data in terms of different quality parameters for evaluating the effect of storage structure was collected at an interval of ten days for a period of sixty days. The samples were analyzed in the laboratory of Farm Structures and Institute of Food Science & Technology, Sindh Agriculture University Tandojam, Pakistan. The ambient temperature and relative humidity of the storage location was determined by using dry and wet bulb thermometers during the experimental period. The following onion quality parameters were determined before and during storage period.

Physiological loss in weight

For determining weight loss, samples were randomly selected and marked. The weight of marked samples were weighed before storing and accordingly after 10 days interval. Weight loss of onion bulbs was calculated and expressed in percentage using the following relation (Soomro et al., 2016):

$$PLW\ (\%) = \frac{W_i - W_d}{W_i} \times 100$$

Where

PLW = Physiological loss in weight; W_i = Initial weight of sample; W_d = Weight of sample at an interval of ten days.

Rotting

Rotted onion was measured by its physical observation of texture, flavor and color around the neck, and was expressed in percentage using the following relation (Sohany et al., 2016):

$$\text{Rotting (\%)} = \frac{\text{Number of rotted bulbs}}{\text{Total number of bulbs}} \times 100$$

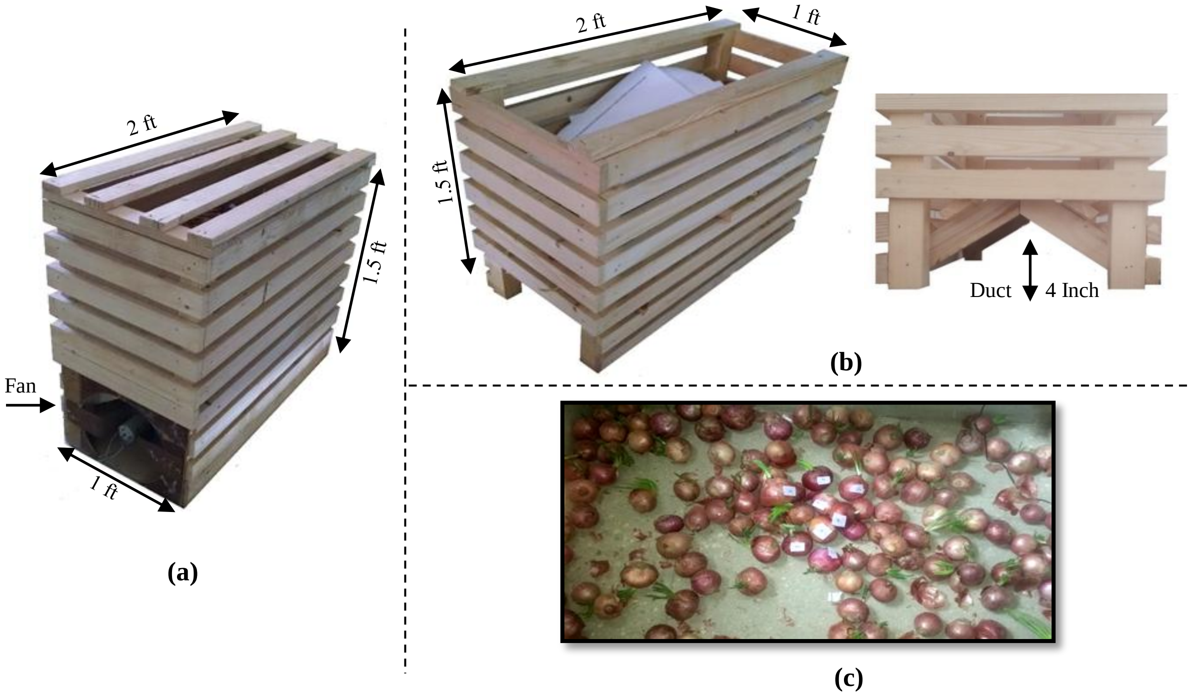

Fig. 1 (a) Different storage methods forced ventilated wooden structure (b) naturally ventilated wooden structure and (c) traditional method

Sprouting

The incidence of sprouting of onion was measured manually by counting the number of sprouted bulbs to total number of onion bulbs kept in storage, and was expressed as percentage using the following relation (Soomro et al., 2016):

$$\text{Sprouting (\%)} = \frac{\text{Number of sprouted bulbs}}{\text{Total number of bulbs}} \times 100$$

Firmness (lbs)

The firmness of onion bulbs was determined using Penetrometer (model FT 011). The onion sample was placed on a hard surface, where the force was applied to the surface of the onion bulb allowing the probe of the penetrometer to penetrate the bulb tissue. The force taken to penetrate each tissue was recorded as a measure of firmness of the onion bulb (Rashidi et al., 2010).

Statistical analysis

Analysis of variance (ANOVA) was performed using factorial analysis (two ways) to assess the significance among various factors and their interactions by using Statistics software (Statistix Ver. 8.1).

Results and Discussion

An increasing trend was observed for relative humidity in all three types of storage methods. The relative humidity with 63% was observed to be highest in naturally ventilated wooden structure, followed by forced ventilated wooden structure and traditional method (Fig. 2a). Ambient temperature in all the storage structures showed an increasing trend with increasing storage period. The maximum ambient temperature with 26 ºC was recorded in traditional storage method, followed by natural ventilated wooden structure and force ventilated wooden structure (Fig. 2b). The increase and variation in temperature and humidity can be attributed to the respiration of onion bulbs. Islam et al. (2019) for their study reported that the temperature was observed to more for the batches that had higher disease incidence. Basediya et al. (2013) reported that the respiratory heat mainly depends upon the temperature, loss of moisture mainly depends on relative humidity.

Table 1 Mean squares for storage structure, storage time and their interaction for onion bulb quality parameters

Source of variation	Weight loss (%)	Rotting (%)	Sprouting (%)	Firmness (lbs)
Storage structure	39.12**	237.9**	57.4**	8.35**
Storage time	291.0**	164.2**	103.6**	11.1**
Structure × Time	5.15**	28.3**	3.41**	0.38**

Note: ** represents significant ($p \leq 0.05$).

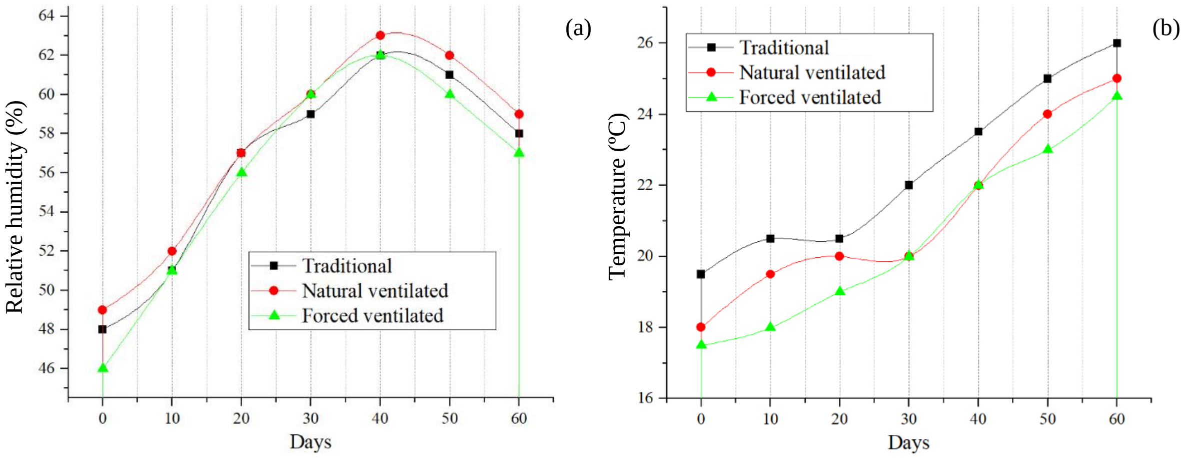

Fig. 2 Relative humidity (a) and temperature (b) for different storage structures

Physiological loss in weight (%)

The physiological loss in weight is graphically represented in Fig. 3a. An increasing trend of loss in weight was observed with respect to increasing storage days in all three storage structures. The maximum weight loss of onion bulbs with 23.5% was observed under traditional method, followed by natural ventilated wooden structure (19.7%) and forced ventilated wooden structure (14.8%). The results further statistically revealed that the storage structure, storage period and the interaction between them were significantly different (Table 1). These losses may be due to the moisture loss during respiration of onion bulbs. Petropoulos et al. (2017) stated that water loss is the key limiting factor that defines the length of the storage, because excessive water loss results in both bulb weight losses and quality loss that affect the marketability of the product. Similar results were also observed by Bogevska et al. (2014), who reported that physiological weight loss in onion bulbs was observed to be more under traditional open ground method then those of nylon bags. The results of the present study are in agreement with the findings of Nabi et al. (2010) who reported a significant difference in weight loss, sprouting and rotting of onion bulbs when stored in different storage structures i.e. cold store, cemented room and mud room for four months. Their results revealed an increasing loss throughout the study where the highest values were reported for the onion bulbs kept under cemented storage structure, while the lowest were for cold storage. Medlicott et al. (1995) observed that forced air storage bins significantly improved the quality of onion bulbs. Although the onion bulb is suitable for long-term storage, losses resulting from loss of moisture, sprouting and particularly microorganism spoilage are a serious problem during storage (Petropoulos et al., 2017; Yoo et al., 2019).

Rotting (%)

The rotting of onion bulbs increased throughout the storage period (Fig. 3b). The rotting of the bulb was initially zero, which after storage was found to be maximum (26.8%) in traditional method, followed by naturally ventilated wooden structure (9.5%) and forced ventilated wooden structure (7.4%). It was observed that values for traditional method was significantly higher than other storage methods. The analysis of variance for storage structure, storage period and the interaction between them were also found to be statistically different ($p \leq 0.01$). The results are in agreement with Priya et al. (2014), who reported that wooden packed storage structure fully ventilated from bottom allowed sufficient ventilation for maintaining the relative humidity. Rotting is a biological activity, resulting from the degradation of bulbs at high temperature (Khan et al., 2004), where reducing the temperature according to its acquired optimum conditions can reduce the losses (Nabi et al., 2010). The impact of rots involves a decrease in the quality and quantity of onion, affecting its market value (Shehu & Muhammad, 2011). In fruits and vegetables, fungi, especially moulds are considered to be the most important pathogens under both tropical and sub-tropical conditions (Adebayo & Diyaolu, 2003). Maini & Chakrabarti (2000) with higher temperature of 30 and 35 ºC observed higher rotting and loss in weight as compared to lower temperature (20 - 25 ºC) during five months of storage period in natural ventilated straw cottage. Ramin (2015) for his study concluded that onions kept for a longer period at higher temperature resulted with higher rotting incidence. Ranpise et al. (2001) reported that the storage temperature of 15 ºC along with relative humidity of 50 to 70% could be helpful to reduce rotting and desiccation to a desired level to lengthen the storage life of onion bulbs, they further concluded that the storage methods having ventilation at the base and centre with raising floor attained minimum losses.

Sprouting (%)

The sprouting percentage as shown in Fig. 3c increased with increasing days of storage. The highest sprouting in onion bulbs with 15.2% was observed in traditional method, followed by natural ventilated structure (11.2%) and forced ventilation structure (7.8%). ANOVA was also observed to be significantly different for storage structure, storage period and the interaction between them (Table 1). The increased respiration rate may be attributed to the increased need for energy metabolism for bulbs to sprout. Sprouting and rooting are the main factors which cause onion deterioration during long-term storage (Adamicki, 2005). Priya et al. (2014) observed lowest sprouting and microbial spoilage for the onion bulbs which were stored in a controlled atmosphere when compared to traditional storage structures i.e. bag, room and bamboo. Gubb and MacTavish (2002) reported that the quality of bulb is significantly affected by the water loss, occurrence of sprouting and rooting, and the changes in chemical composition. Storage temperature and particularly high temperatures are the main factor for shoot growth inhibition (Yoo et al., 1997). Doug (2004) for his study reported low sprouting in onion bulbs when kept at low temperature. Sohany et al. (2016) observed that the onion bulbs stored at ambient condition (28 °C & 75% relative humidity) showed highest weight loss, sprouting and rotting as compared to those kept in storage at a temperature of 2.5 °C for 60 days.

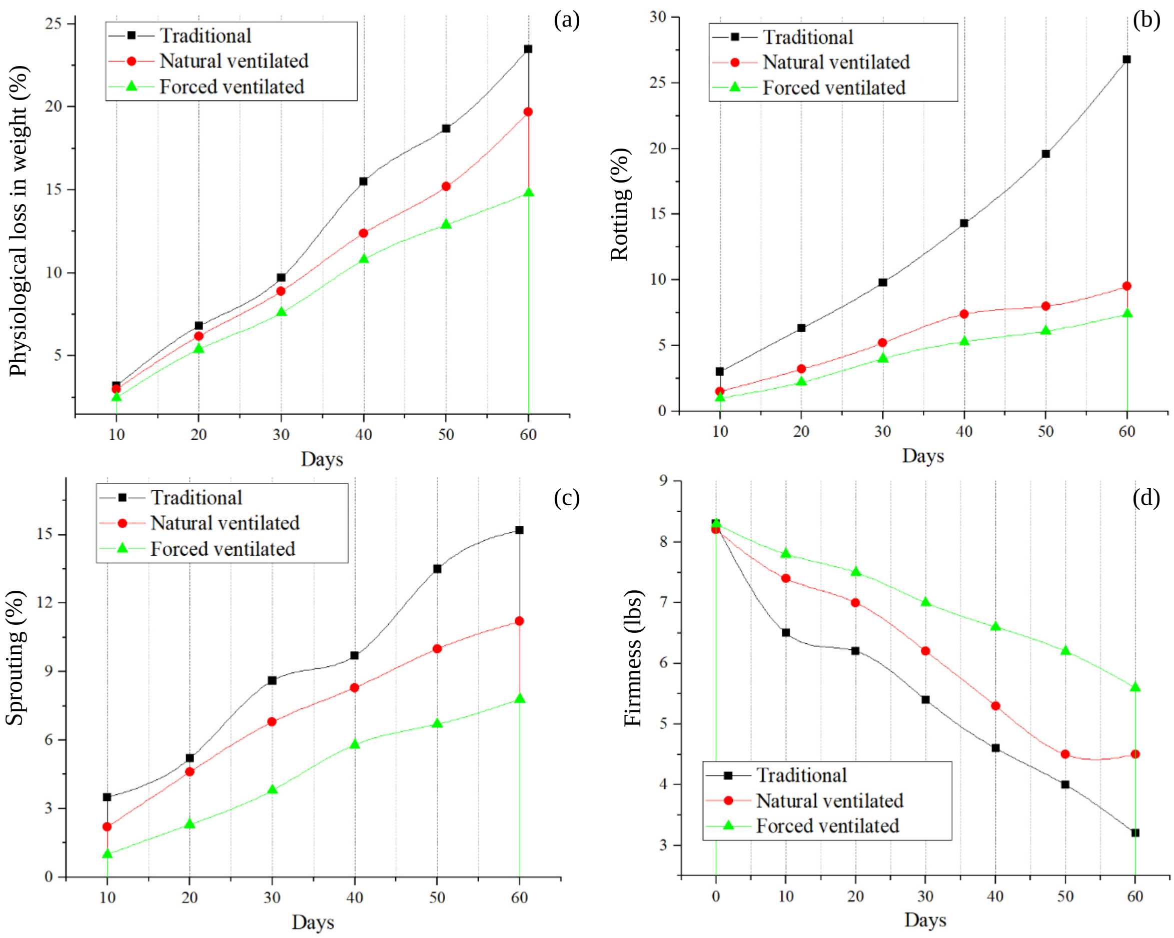

Fig. 3 Effect of storage method and time on physiological weight (a), rotting (b), sprouting (c) and firmness (d).

Firmness (lbs)

The firmness of onion bulbs during and days after storage decreased for the entire storage period. The highest firmness (initially) was observed to be 8.3 lbs which then decreased to 5.6, 4.5 and 3.2 lbs for forced ventilated wooden structure, naturally ventilated wooden structure, and traditional method respectively (Fig. 3d). The results as presented in Table 1 represents that the storage structure, storage period and the interaction between them were also found to be significantly different ($p \leq 0.01$). Similar results were obtained by Rodrigues et al. (2012) for the onions kept for 3 and 6 months of storage, they reported that firmness intended to decrease with increasing days of storage. A reduction in firmness was observed with high temperature, resulting in rapid degradation of quality of onion bulbs (Hole et al., 2002; Coolong et al., 2008). Chope et al. (2006) while observing the effect of storage of onion bulbs of cvs. Renate, Ailsa Craig and SS1 observed a significant decrease in firmness. Warade et al. (1997) investigated the effect of modified storage structure with bottom and central ventilation on quality of onion bulbs, they concluded that modified storage showed better quality with minimum losses as compared to traditional storage methods. Islam et al. (2019) for their study reported that tracking the temperature and relative humidity during the storage of onions is helpful in improving the quality of onion bulbs. Storage conditions such as temperature and relative humidity are necessarily to be maintained for acquiring high quality bulbs until they are consumed (Medlicott et al., 1995; Brewster, 2008).

Conclusion

The results of conducted study concluded that the storage time and storage method had a significant effect on the quality of onion bulbs. Force ventilated wooden structure maintained lowest weight loss, rotting and sprouting percentage with the highest firmness of onion bulbs throughout the experiment, followed by naturally ventilated wooden structure and traditional method. Physiological loss in weight, rotting and sprouting of onion bulbs showed an increasing trend throughout the storage period. However, the firmness of the onion bulb decreased with increasing storage period. Ambient temperature and relative humidity throughout the experiment varied from 17.5-26 ºC and 46-63%, respectively. Ambient temperature and relative humidity were observed to be lower in forced ventilated wooden structure, followed by natural ventilated wooden structure and traditional method. Forced ventilated wooden structure among other storage structures resulted to be better in terms of maintaining the quality of the onion bulbs, the adoption of this structure is therefore strongly recommended at farm level.

Author Contribution Statement: Shakeel Hussain Chattha and Benish Nawaz Mirani contributed in study conception and design. Shakeel Hussain Chattha and Zaheer Ahmed Khan contributed in performing the experiments. Shakeel Hussain Chattha and Khalil Ahmed Ibupoto supervised and contributed in interpretation of data. Shakeel Ahmed Soomro contributed in analysis of data and wrote the paper.

Conflict of Interest: The authors declare that they have no conflict of interest.

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